Maintenance Decision Support System (MDSS) Project

MDSS Prototype Development Plan

For

The Federal Highway Administration
Road Weather Management Program

Abridged Version

11 June 2001

NCAR

Table of Contents

Acronym Glossary

CRREL	Cold Regions Research and Engineering Laboratory, an Army facility
DICAST	Dynamic Intelligent foreCAST
DOT	Departments of Transportation
DSS	Decision Support System
ESRI	Environmental Systems Research Institute
ETL	Environmental Technology Laboratory, a NOAA facility
FHWA	Federal Highways Weather Association
FSL	Forecast Systems Laboratory, a NOAA facility -
HOTO	Office of Transportation Operations
IP	Intellectual Property
LDADS	Local Data Acquisition and Dissemination System
MDSS	Maintenance Decision Support System
MIT/LL	Massachusetts Institute of Technology - Lincoln Laboratory
MOS	Model Output Statistics
NSF	National Science Foundation
NSSL	National Severe Storms Laboratory
NOAA	National Oceanic and Atmospheric Administration
NCAR	National Center for Atmospheric Research
OCD	Operational Concepts Description
RWMP	Road Weather Management Program
STWDSR	Surface Transportation Weather Decision Support Requirements
VAMS	Value Added Meteorological Services
WIST-DSS	Weather Information for Surface Transportation Decision Support System

MDSS Prototype Development Project Plan

1 Scope

This plan describes the tasks, milestones, deliverables, and design elements for the development of a prototype Maintenance Decision Support System (MDSS). High level descriptions of the technical components of the MDSS are described in the appendices. This document focuses primarily on activities performed in fiscal year 2001 (October 2000 through September 2001).

2 Related Documents

For background on the FHWA Road Weather Management Program and additional information on the MDSS Project, the reader is directed to related project documents listed in Table 1.

Table 1 Related Documents

Document and/or Web Sites	**Source**
Presentations and documents for the Surface Transportation Weather Decision Support Requirements (STWDSR) project: http://www.mitretek.org/its/stwdsrt/	Mitretek Systems, Inc.
STWDSR– Draft Version 1.0 (Needs Analysis) http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9dc01!.pdf	Federal Highway Administration
STWDSR– Operational Concept Description (OCD) Draft Version 2.0 http://www.itsdocs.fhwa.dot.gov/jpodocs/EDLBrow/401!.pdf	Federal Highway Administration
STWDSR--Preliminary Interface Requirements (PIR), Draft Version 2.0 http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@701!.pdf	Federal Highway Administration
Department of Transportation, Federal Highways Administration Road Weather Management Program; Maintenance Decision Support System Operational Test Request for Application	Federal Highway Administration

3 Introduction

The development of a prototype MDSS is part of the Surface Transportation Weather Decision Support Requirements (STWDSR) initiative. Mitretek Systems, Inc. is conducting the STWDSR initiative for the FHWA's Office of Transportation Operations (HOTO) Road Weather Management Program. The documents STWDSR V1.0 and STWDSR V2.0 give background information on the program and an initial needs analysis for decision support associated with winter road maintenance. These documents explain the process used by the FHWA and stakeholder groups (users, vendors, and researchers) to produce an initial operational concept for the Weather Information for Surface Transportation Decision Support System (WIST-DSS). The WIST-DSS is the conceptual system on which the STWDSR are levied.

The STWDSR project initially focused on decision support requirements for winter road maintenance managers. An initial needs analysis has been defined for surface transportation decision makers. In future phases of the project, requirements for additional transportation decision maker groups will be developed. The STWDSR project has two primary objectives:

- To provide requirements, at a high level, that can be allocated to lower levels, within a spiral evolutionary process of WIST-DSS deployment; and,

- To identify requirements on external information resources for the WIST-DSS that can be addressed by programs within the FHWA and by inter-agency programs with the meteorological community and others.

The objective of the MDSS effort is to produce a prototype tool for decision support to winter road maintenance managers. While it is recognized that other such tools exist and are under development, there is an important feature of MDSS that makes it unique. The MDSS is based on leading diagnostic and prognostic weather research capabilities (high resolution numerical forecast models and experimental algorithms) and road behavior (surface and subsurface), which are being developed at national research centers.

It is anticipated that components of the prototype MDSS system developed by this project will ultimately be deployed by road operating agencies, including state departments of transportation (DOTs), and generally supplied by private vendors (often called Value Added Meteorological Services or VAMS).

The FHWA through the STWDSR process selected six national research centers to participate in the development of the prototype MDSS. They were selected because of the applicability of their expertise to the MDSS task. The participating national labs are:

- Cold Regions Research and Engineering Laboratory (CRREL), an Army facility
- National Center for Atmospheric Research (NCAR), a National Science Foundation (NSF) facility

- Massachusetts Institute of Technology - Lincoln Laboratory (MIT/LL), an Air Force facility
- National Severe Storms Laboratory (NSSL), a NOAA facility
- Environmental Technology Laboratory (ETL), a NOAA facility
- Forecast Systems Laboratory (FSL), a NOAA facility

4 MDSS Project Goal

The FHWA, through the STWDSR process, collected and refined the needs of the winter road maintenance community and identified the research products that could reasonably be expected to address and improve the performance of the road maintenance practitioner.

The MDSS project goal is to develop a prototype capability that:

1. Capitalizes on existing road and weather data sources,
2. Augments data sources where they are weak or where improved accuracy could significantly improve the decision-making task,
3. Fuses data to make an open, integrated and understandable presentation of current environmental and road conditions,
4. Processes data to generate diagnostic and prognostic maps of road conditions along road corridors, with emphasis on the 1- to 48-hour horizon (historical information from the previous 48 hours will also be available),
5. Provides a display capability on the state of the roadway,
6. Provides a decision support tool, which provides recommendations on road maintenance courses of action, and
7. Provides all of the above on a single platform, with simple and intuitive operating requirements, and does so in a readily comprehensible display of results and recommended courses of action, together with anticipated consequences of action or inaction.

During a FHWA review of candidate technologies that could address road weather problems, it became clear that several candidate technologies currently exist at national laboratories, but the new technologies needed to be integrated, refined, and tailored to address road maintenance weather issues. It also became clear that new and focused research must be conducted to address specific winter maintenance decision support needs that are not addressed by current technologies.

5 Constraints

The FHWA has assigned a 3-year timeframe for the MDSS project. The first year will be dedicated to working with the state DOTs on the development of a prototype MDSS, which will demonstrate the scope and capabilities of components that address user needs identified in the OCD, and that can reach Initial Operating Capability (IOC) in one or more operational tests by the end of the second year.

The second and third years will demonstrate and evaluate operation of selected prototype components in one or more operational systems that deliver decision support to winter road maintenance. The FHWA intends to select and make awards to the operational test sites, as well as continuing funding to the prototype developers, in order to transfer the prototype technologies and integrate them into operational systems.

The amount of work required to coordinate six national labs and integrate their technical components (algorithms, methods, and techniques) toward the development of a single prototype system should not be underestimated. This is a complex process and one that will provide several challenges. The total budget for the first year is only $900,000, which will be divided between the six national labs.

A preliminary sorting exercise of candidate technologies was conducted in FY2000. Because of the project's time constraint, only existing technologies will initially be incorporated into the prototype MDSS. In addition, technologies were chosen that would provide the most benefit in terms of addressing user needs. A minimum number of technical components (modules) were identified and included to ensure that the prototype MDSS will address selected user needs from the OCD, based on the importance of the those needs to transportation performance and the feasibility of serving the needs with the selected technologies.

6 MDSS Prototype – User Needs

The STWDSR work documented in the OCD and the PIR identifies a number of customer needs in terms of decisions made to treat weather threats and the quality of decision support. The customer's requirement is stated as, "better transportation performance through decision support for treating weather threats based on information on treatment assets, environmental conditions and traffic conditions."

The OCD emphasizes the fusion of environmental, transportation and treatment asset information relative to specific treatment decisions. The OCD further prioritizes the operational scale of decisions, in between longer range asset planning and immediate (maintenance equipment operation) decisions. The OCD recognizes that there are numerous external information sources to be integrated. The PIR covers the range of external information sources. It is clear that substantial benefits can be realized if weather forecasts and road condition predictions are improved, more specific, more timely, and tailored for surface transportation decision makers. New data sets (e.g., ESS, wind profiler, GPS, thermal maps, etc.), advanced forecast models, data integration techniques, and research results must be utilized.

The OCD defines decisions and clusters of closely related decisions based on user responses in stakeholder meetings. Three clusters (with their constituent decisions) have been selected for focusing the MDSS prototype development:

- Monitor Conditions (beginning ~48 hours before event start time)
    - Become aware of weather threat
    - Monitor weather threat
    - Identify weather threat occurrence

- Activate Staff (beginning ~15 hours before event start time)
    - Put supervisory staff on event schedule
    - Split crew shifts
    - Call in crews

- Mid-Storm Management (beginning ~1-3 hours before event start time)
    - Dispatch crews to treat (ice spots)
    - Request out-of-jurisdiction resources
    - Coordinate emergency management
    - Coordinate public (traveler) information
    - Manage incidents
    - Close roads
    - Monitor crew working time and condition
    - Rest crews
    - Re-evaluate storm intensity and duration
    - Determine that level-of-service goal is reached

There are many levels and types of users, and each DOT is organized differently. The MDSS prototype will be developed in a manner that allows potential users to determine if the product and display concepts have merit. The traceability between needs and the prototype components will be defined and maintained jointly by Mitretek, DOT participants, and the labs.

Road maintenance managers indicated that it is very important to have better information (forecasts) on the expected road condition well before the event begins. The users will act conservatively if they perceive that forecast information is unsure or nonspecific. Critical decisions (e.g., monitor conditions, assign crews, activate staff, select treatment strategy, etc.) are made approximately 48 hours prior to the event start time.

Based on discussions with the FHWA and results of the STWDSR process, the most important environmental factors that have been identified to date for supporting maintenance decisions include the following:

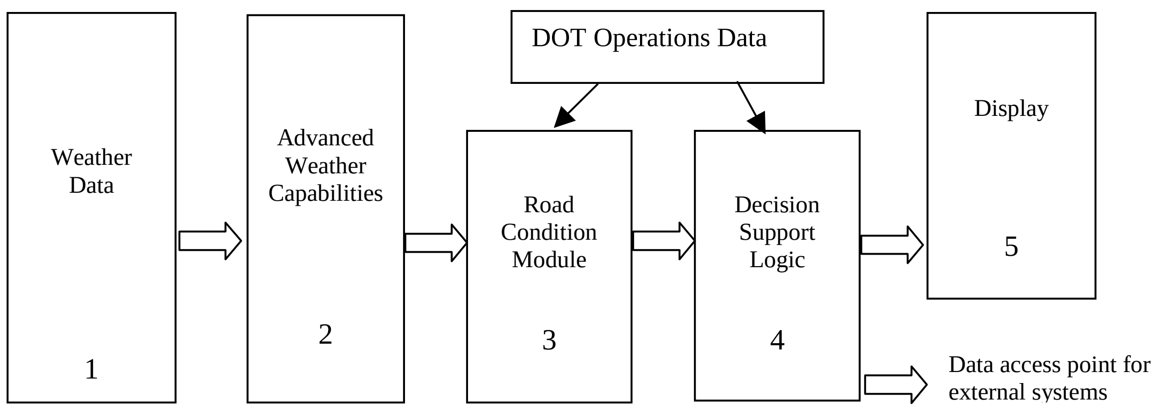
- “Event” definition with respect to start and stop times
- Precipitation characteristics (type, amount, rate)
- Road condition (temperature, chemical concentration, coverage by liquid phases)
- Snow status (depth on road and drift patterns)
- Risk (confidence and/or probabilities associated with data elements)

These priorities require review and refinement by the six laboratories, and later by discussions with stakeholders.

In summary, the priorities of the MDSS include developing capabilities for improving weather and road condition information (diagnostic and prognostic), developing a DSS capability to support operational-scale treatment decisions, and tailoring the DSS interface for the winter roads maintenance manager. It must be understood that until the MDSS is integrated with a VAMS system in an operational environment, the benefits and limitation of the prototype technology cannot be fully assessed. Assessing the benefits of MDSS components is the major focus of the operational test phase of the project, in FY2002 and FY2003.

7 Conceptual System Structure

With the user needs in mind (as described in section 6), a conceptual structure of the prototype MDSS has been developed. The prototype MDSS is divided into five primary elements (see diagram below).



Each element of the prototype will be “populated” in order to have a functioning prototype MDSS. Element 1 will include various types of weather data. Element 2 will generally include new environmental prediction technologies provided by the research labs. These technologies will include mesoscale (high resolution) model and ensemble weather data, algorithms, weather data processing systems, etc. Element 3 will contain the algorithms necessary to generate road condition information from environmental and operational information. Element 4 will contain the algorithm logic necessary (e.g., rules of practice) to address specific road maintenance decisions. Element 5 will be the display vehicle used to demonstrate the prototype MDSS capabilities. Additional information related to these components is provided below.

7.1 MDSS Element 1: Weather Data

For the FY2001 MDSS effort, standard weather sources (e.g., NOAAPORT, LDADS) and nonstandard weather data (e.g., road weather sensor data, video images, advanced numerical forecast model output) will be used. A significant amount of the work in element 1 will be to find the appropriate and most efficient sources of data needed for the prototype. Surface data will be critical for the system; therefore, a significant effort will be made to acquire surface weather data, particularly road weather sensor data, in the region covered by the MDSS.

7.2 MDSS Element 2: Advanced Weather Capabilities

Element 2 is the core weather processing module for the prototype MDSS. Using a "winnowing" process that took into account project constraints, a number of candidate technologies were identified for inclusion in MDSS element 2. These include:

- Ensemble forecasts (FSL and NSSL)
- Precipitation-type algorithms (NSSL)
- Weather condition diagnosis (e.g., visibility) from video cameras (LL)
- Data fusion algorithms and advanced forecasting technologies (NCAR)

These technologies will be integrated within the MDSS to produce weather diagnoses and forecasts. Contained in this module will be a "weather engine" that will generate point specific weather information for selected locations along road corridors. In addition to the weather data values, system output will include a measure of confidence for weather parameters. The confidence or probability information will be utilized by the DSS (MDSS element 4).

7.3 MDSS Element 3: Road Condition Module

The road condition module will ingest environmental data and integrate it with DOT operational data (e.g., traffic, treatment, road temperatures, etc.) to generate road condition information.

Several technologies for diagnosing and predicting road condition were identified for inclusion in MDSS element 3. The candidate technologies for inclusion during the first year of development include:

- Road temperature algorithm (CRREL)
- Road surface friction algorithm (CRREL)
- Road chemical concentration (CRREL)
- Snow drift algorithm (CRREL)

Output from these algorithms will be utilized within element 3 and exported to element 4. It is anticipated that output from the road condition algorithms will eventually be cycled back into element 2 in a manner that will provide additional intelligence to the system, but resource constraints will not permit this during the first year.

7.4 MDSS Element 4: Decision Support Logic

During the first year of the project, the focus of element 4 will be to develop a capability to provide decision support for a select number of user decisions. This element requires an integration of environmental, road condition, and DOT operations data. The *Monitor Conditions* and *Activate Staff* decision cluster will be the focus of the DSS development effort in the first year.

To extend from the display of predicted conditions to actual decision support products, *rules of practice* algorithms will be developed that suggest courses of actions (based on predicted conditions) and potential consequences of inaction. These decision support algorithms will, for this initial MDSS effort, be based on widely accepted practices by state DOTs. During MDSS review meetings, stakeholders will be queried to determine the details of the condition/action relationships and the feedback will be considered during the MDSS development process.

7.5 MDSS Element 5: Display

Element 5 is the display module for the prototype MDSS. Several candidate display technologies were discussed. In an effort to optimize software engineering resources (to provide as much time and funding as possible to the core development tasks) a display platform (or demonstrator vehicle) for the initial MDSS project will be utilized. The display technology chosen for the first year development is a GIS based solution. The software package chosen for the display is:

- ArcView by ESRI (CRREL to configure)

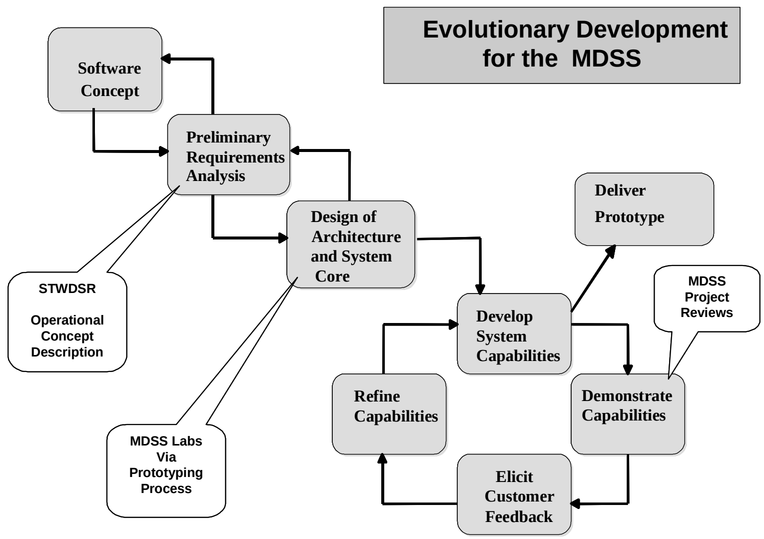
ArcView is a commercial-off-the-shelf desktop GIS system developed by Environmental Systems Research Institute (ESRI), which has the capability to display, as overlays, point or gridded data, and numerous map data sets.

Note: Technical overview descriptions of the major MDSS prototype components are provided in the appendices.

8 Engineering Approach for the MDSS Prototype

The prototype MDSS must be developed rapidly and include input from several national laboratories. Each lab will develop capabilities and refine those capabilities during the project duration. At appropriate times during the development effort, labs will provide snapshots of their technologies to be integrated into the core system.

An evolutionary approach will be used to develop and implement software for the MDSS, except for any commercial off-the-shelf (COTS) components. Early examples of the system are presented to the stakeholders and the system is refined and enhanced based on feedback. The cycle continues until development time runs out (schedule constraint) or funding for development runs out (resource constraint). A graphical representation of the Evolutionary Delivery approach is provided below.

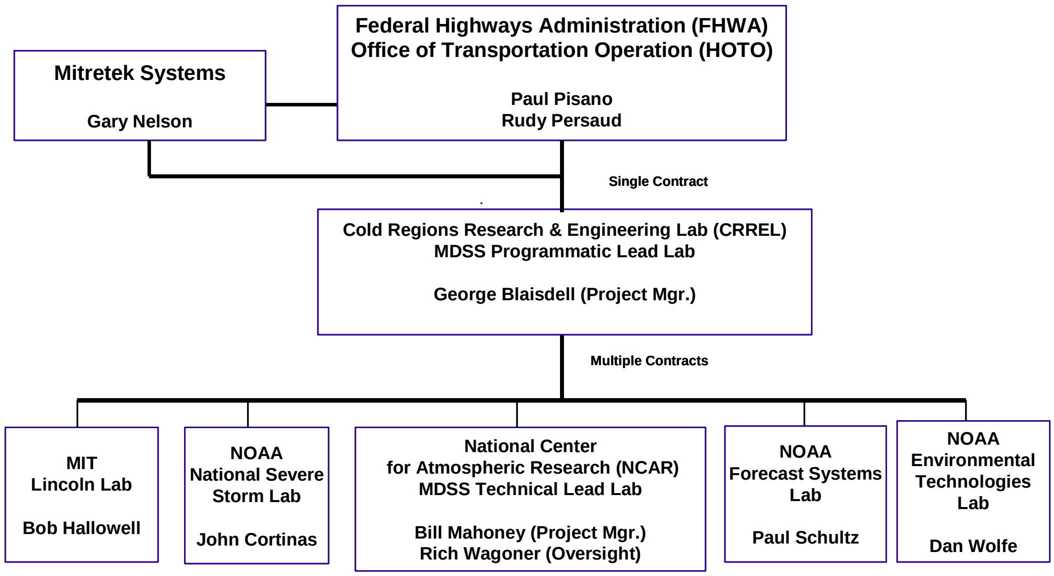


MDSS development environments will continue to be used during subsequent years to support ongoing MDSS developments, enhancements, and demonstration activities. MDSS development environments will be established at both NCAR and CRREL. The NCAR development environment will be used to develop the "weather engine" that will provide environmental data to the road condition, DSS and display components. The CRREL development environment will be used to develop the road condition, DSS and display elements of the MDSS. Stakeholders will participate in reviews of the MDSS displays and products during the prototype phase.

9 Project Organization

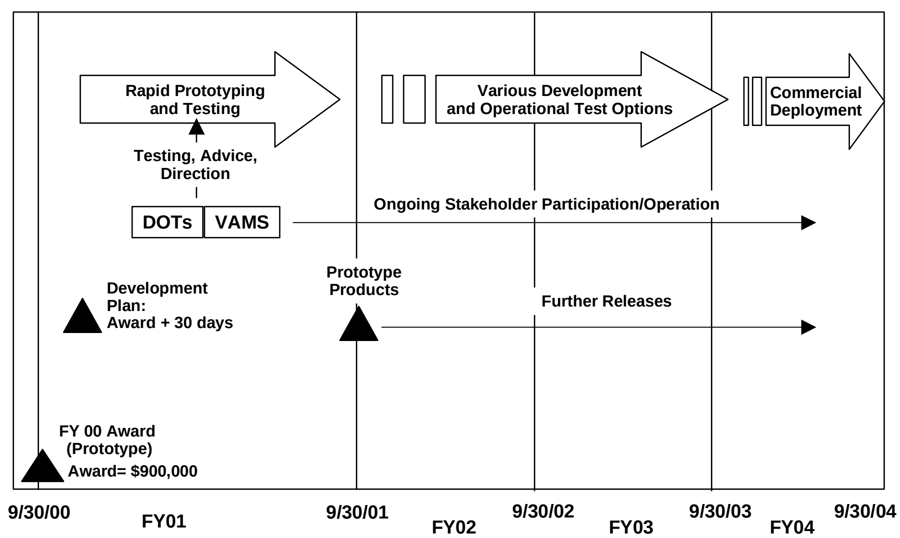
The MDSS project is a collaborative effort between the national laboratories, Mitretek Systems, and the FHWA. An organization chart of the MDSS Project is provided below:

Maintenance Decision Support System (MDSS) Project



10 Schedule

The MDSS Project spans a three-year period beginning FY2001. A high-level project schedule is shown below.



The major objective of the MDSS Project is to conduct a demonstration of the prototype MDSS by 30 September 2001. The primary objective of the demonstration is to validate the concept of an MDSS, which successfully utilizes the advanced technical capabilities provided by the national labs. There will be three review benchmarks during the FY2001 effort:

First Review: This will occur in February 2001 and will convene DOT users who will review the prototype concept relative to their operational needs. Effort will be made to include DOTs who are potential operational test sponsors. It is expected that participation in the prototype phase will be a significant qualification for operational test participation.

Second Review: This will occur in June 2001 and will include both DOTs and VAMS. This review will demonstrate progress and allow stakeholders to discuss system design elements with the development team. A review and discussion of the operational test plan, which will be conducted in year two and three, will also be part of the second review meeting, and is expected to be essential for participation by candidates for the operational test phase.

Third Review: The third major milestone will occur in September 2001. The primary objective of the third review is to demonstrate the prototype MDSS components that will be used in the operational test phase.

11 Overview of the Development/Operational Test Phase (FY2002-2003):

The MDSS Prototype work described in this Project Plan is funded up to the end of FY2001, on September 30, 2001. The FHWA plans to fund a second phase of development that will involve further development, and possibly an operational test of MDSS Prototype products. The development/test phase will continue funding of the national labs. In addition, a competitive award may be made to one or more public/private partnerships for participation in operational tests.

Interested applicants for the operational test phase were solicited through a Notice of Intent (NOI) released on April 17, 2001 and found at www2.eps.gov, search on solicitation number DTFH61-01-R-00069. Plans for the operational test are being reviewed subsequent to that notice, and changes will be notified to respondents to the NOI. The NOI also serves as the invitation to the second MDSS review meeting, to be held June 21-22 at the CRREL facility in Hanover, NH. FHWA will make a decision on details of the development/tast phase for release at the second MDSS review meeting, and by further public notice.

For any of the development/test options, the FHWA will continue participation by public and private sector stakeholders. For an operational test, public and private partners will be sought, probably by competitive award. Those partners will perform integration and operational testing of a system that meets highway operators' needs for decision support for winter road maintenance management. The FHWA has funded development, by the national labs, of advanced components for processing and fusing environmental and other information, and displaying information to support more efficient and effective ice treatment and snow removal on roads. The national labs will continue through any development or test period to develop their components further and to integrate them into operational systems. Private sector vendors of Road Weather Information Systems (RWIS) will integrate the advanced components into their systems for use by public sector agencies responsible for winter road maintenance. The integrated system will be operationally tested over at least one winter of road maintenance operations. One or more partnerships, that may consist of multiple public agencies and private vendors, will be selected for award of Federal funding for participation in the system integration and operational test. At the end of any development/testing phase, the FHWA expects commercial deployment of open and integrated systems. Such systems may combine components with intellectual property (IP) rights held by both the national labs and the commercial deployers.

APPENDIX A

Points of Contact: MDSS Prototype Development Team

George Blaisdell CRREL 72 Lyme Road Hanover, NH 03755-1290 Ph: 603-646-4474 Email: blaisdell@crl02.crrel.usace.army.mil	Rosa Affleck CRREL 72 Lyme Road Hanover, NH 03755-1290 Ph: 603-646-4662 Email: Rosa.T.Affleck@erdc.usace.army.mil
John Cortinas National Severe Storms Laboratory 1313 Halley Circle Norman, Oklahoma 73069 Ph: 405-366-0482 Email: cortinas@nssl.noaa.gov	Rudy Persaud (MDSS Agency Technical Representative) U.S. DOT, Federal Highway Administration Turner Fairbank Highway Research Center 6300 Georgetown Pike McLean, VA 22101-2296 Ph: 202-493-3391 Fax: 202-493-3419 Email: Rudy.Persaud@fhwa.dot.gov
Robert G. Hallowell MIT Lincoln Laboratory 244 Wood Street Lexington MA 02420-9180 Ph: 781-981-3616 Fax: 701-781-0632 Email: bobh@mitll.edu	Paul Pisano (Road Weather Management Program Director) U.S. DOT, Federal Highway Administration HOTO-1 400 Seventh Street, SW Washington, DC 20590 Ph: 202-366-1301 Fax: 202-366-8712 Email: Paul.Pisano@fhwa.dot.gov
Bill Mahoney NCAR 3450 Mitchell Lane Boulder CO 80301 Ph: 303-497-8426 Fax: 303-497-8401 Email: mahoney@ucar.edu	Paul Schultz NOAA/Forecast Systems Lab 325 Broadway, R/FS1 Boulder CO 80303 Ph: 303-497-6997 Fax: 303-497-7262 Email: schultz@fsl.noaa.gov
Bill Myers NCAR 3450 Mitchell Lane Boulder CO 80301 Ph: 303-497-8426 Fax: 303-497-8401 Email: myers@ucar.edu	Rich Wagoner NCAR 3450 Mitchell Lane Boulder CO 80301 Ph: 303-497-8404 Fax: 303-497-8401 Email: wagoner@ucar.edu
Gary Nelson Mitretek Systems, Inc. 600 Maryland Ave., SW Suite 755 Washington DC 20024 Ph: 202-488-5718 Fax: 202-863-2988 Email: gnelson@mitretek.org	Dan Wolfe **NOAA/ETL** 325 Broadway Boulder, CO 80303 Ph: 303-497-6204 Email: dwolfe@etl.noaa.gov

APPENDIX B

MDSS Technology Description

MDSS GIS Display System

Originating Organization: Cold Regions Research & Engineering Laboratory (CRREL)

Point of Contact Information:

Rosa Affleck
CRREL
72 Lyme Road
Hanover, NH 03755
603-646-4662
Rosa.T.Affleck@erdc.usace.army.mil

IP Restrictions: CRREL shall grant to the other party a limited, non-exclusive, non-transferable, revocable, royalty free right to access and use CRREL Intellectual Property only for the purpose of performing the work under this project. Separate licensing arrangements may be required for use of CRREL Intellectual Property outside the MDSS operational test. It is likely that the use of commercial products (e.g., commercial off-the-shelf GIS software) will require licenses agreements and these license agreements (purchase of license) will be the responsibility of those using the commercial product.

Mode of Operation: It is envisioned that during the operational test, the MDSS display system may or may not be implemented in whole. That is, the user display capabilities of the vendor and DOT will be reviewed to determine if the MDSS capabilities can be implemented on vendor provided display systems or if it is necessary to implement the MDSS prototype display.

1. Introduction

a. General overview description: The MDSS prototype utilizes a particular brand of commercial GIS software (ArcView). The choice to use a commercial product for the prototype was made for efficiency. There are no technical reasons restricting MDSS display capabilities from being applied to other GIS software (commercial or open software).

b. Scope. This document describes the basic capabilities of the GIS system as related to MDSS concepts. The descriptions should be considered a subset of the total number of features and functions that are envisioned for the MDSS.

c. Definitions, acronyms, abbreviations:

GIS	Geographical Information System
ESRI	Environmental Systems Research Institute, Inc.

d. References. The reader is directed to ESRI ArcView user manuals if information is desired on the GIS commercial software used in the MDSS project.

2. Technology Overview.

The reader is directed to ESRI (http://gisstore.esri.com/) to obtain technical information on the ArcView software system. As noted above, the MDSS prototype was developed using ArcView; however, the use of ArcView does not imply a preference or technical need for this particular commercial package.

3. Interfaces.

a. System interfaces. A personal computer with a, Macintosh, windows 98, Windows 2000, or NT operating system is required to run ArcView. An ArcView software license of also required. The ArcView spatial analyst extension is also needed.

b. User interfaces. ArcView has a built-in Graphic User Interface (GUI). It has the ability to spatially display multiple points, vector, and raster overlays. It has the capability to perform queries, and zoom in and out of a domain of interest. ArcView has a variety of color schemes, and icons to display an overlay. The overlays can be turned on or off by the user(s). Multiple views can be created for a series of events. ArcView has the ability to produce charts, and layouts for presentations.

For the MDSS application, the overlays (layers) will include states boundaries, counties, interstates, weather data, elevation data, major cities, CRREL road condition module outputs, and other pertinent data. The user can zoomed-in for a higher resolution views all the way to city blocks. Locations of winter maintenance or garage and storage facilities can be spatially displayed. It is envisioned that there will be an interface to DOT garage facilities in order to obtain information on chemical supplies and equipment stocks. Color-coded road segment and/or points along the interstates (e.g., from red for worst to green for good) can be used for warning indication for the storm events. With multiple views, one can view the current, predicted, and previous conditions of the road network.

c. Hardware interfaces. A portable computer, Macintosh, Windows 98, Windows 2000, or NT operating system, single license ArcView software with spatial analyst extension.

d. Software interfaces. The MDSS prototype used GIS software from ESRI called ArcView; however, other GIS software (commercial or open) could be used as well.

e. <u>Communication interfaces.</u> The MDSS display will require interfaces to a database system that continually updates based on the latest weather, road condition, and DOT operational data (Ref., MDSS Project Plan).

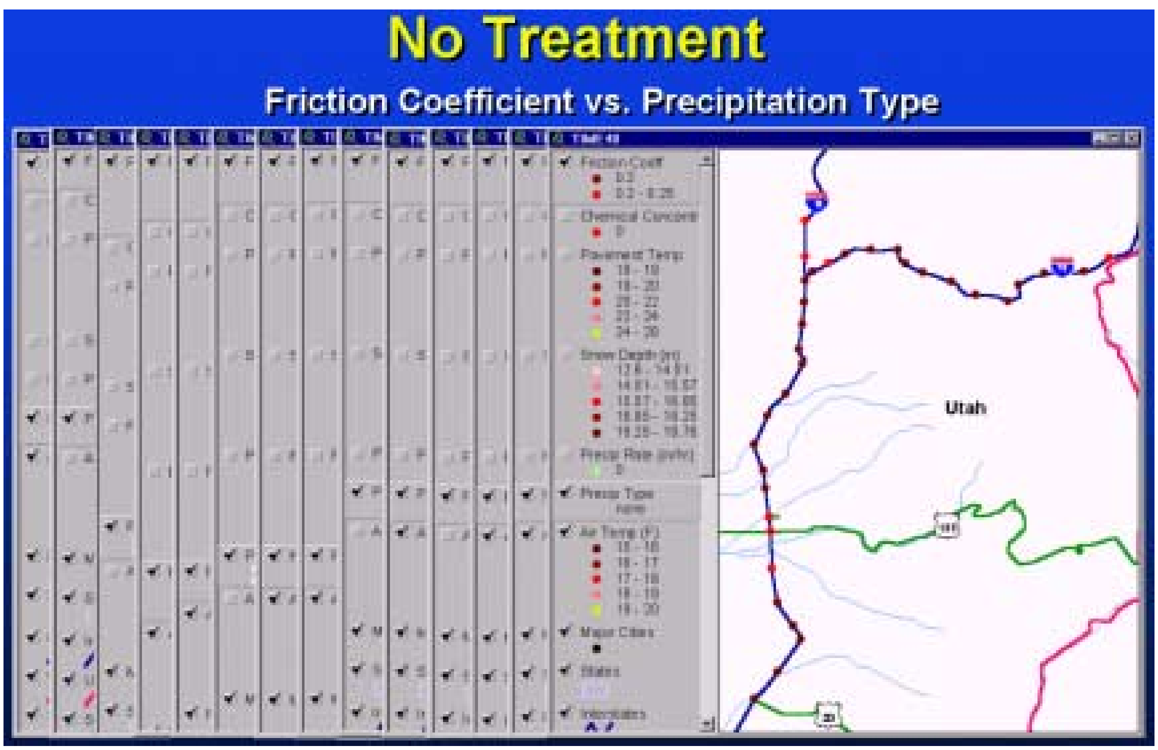
f. <u>Data input format.</u> ASCII files with latitude and longitude for point overlay.

g. <u>Data output format.</u> ArcView's output formats are .shp, .shx and .dbf, which correspond to one overlay file. There are many ways to produce output files for presentation or distribution, one is to create a layout of a view and save it as .tif or .pdf, another way is to print the layout or view directly to the printer.

4. Risk Factors

The MDSS display system contains new concepts being developed by CRREL. As such, the full functionality of this component is still under development. While general system components have been defined and to some extent validated, implementing these capabilities in new computing environments may be challenging and may require further research and development. Recipients of this technology should consider this risk.

Below is a sample output image from the MDSS prototype GIS display.



APPENDIX C

MDSS Technology Description

MDSS Decision Support System (DSS) Concepts

Originating Organization: Cold Regions Research & Engineering Laboratory (CRREL)

Point of Contact Information:
Kevin McLain
CRREL
72 Lyme Road
Hanover, NH 03755
603-646-4428
kevin.mclain@erdc.usace.army.mil

IP Restrictions: CRREL shall grant to the other party a limited, non-exclusive, non-transferable, revocable, royalty free right to access and use CRREL Intellectual Property only for the purpose of performing the work under this project. Separate licensing arrangements may be required for use of CRREL Intellectual Property outside the MDSS operational test.

Mode of Operation: It is envisioned that during the operational test, the MDSS decision support system concepts may or may not be implemented in whole. That is, the capabilities of the vendor and DOT will be reviewed to determine if the MDSS DSS concepts can be implemented in total or if only certain elements of the DSS will be implemented and demonstrated.

1. Introduction

a. General Overview description. The MDSS decision support system concepts described herein have been developed by incorporating concepts from the MDSS Operational Concept Document (OCD) and by incorporating feedback received from participating DOT personnel during the course of this project. It should be noted that only a fraction of the potential MDSS features and functions are described in this appendix, as the MDSS concept development process is ongoing.

b. Scope. The appendix focuses on envisioned features and functions of the graphical user interface component of the MDSS decision support system.

c. Reference. The textual description of the user interface provided in this section corresponds to a graphical presentation on the MDSS user interface made by CRREL at the MDSS First Review Meeting in February 2001 in Boulder, Colorado and should be used to visualize many of the concepts described in this section.

2. Technology Overview

The following is a partial listing of features, functions and map overlays that are envisioned for the MDSS graphical user interface (Ref. CRREL PowerPoint Presentation from MDSS First Review meeting).

- Base map: A detailed street/road network map should be utilized.
- Ability to view weather and road surface condition as overlays (user-selectable) at points/segments of road network.
- Ability to magnify the image of road points and segments (to see more details and to reduce screen clutter).
- Include a timeline capability with sliding window (e.g., +/- 7 days), to quickly capture the appropriate timeframe of interest.
- Include a forward/back "play" function (with manual drag/drop override) to glide more slowly through time and view predicted events and recommended road treatments, as well as to review past history and treatments.
- Include color-coded warning indicators of declining road condition status (client-defined) at various trigger levels (client-defined) – a.k.a. "hot spots".
- Include graph of client-defined variables for warning indication (i.e., road friction, snow depth on road, etc.) for each road segment.
- Provide a recommendation for road treatment options (with client-defined requirements/constraints) showing what, when, where, and how much, in response to the warning/prediction signals. Also provide preliminary crew and equipment notification/preparation information.
- Provide standard and custom truck route maps.
- Provide resource list and availability; trucks (with weight limits and spreader/plow options), crew (phone/pager numbers, next-in-line personnel, last shift worked, overtime accrued, sand/salt stocks, alternative stock sources, etc.).
- Provide ability to view a `Game Plan' or `Logistics Matrix', showing full details of shift times, personnel, truck, material, phone notification time, loading time, treatment time, truck routes (standard and custom), etc.

- The guidance provided by the MDSS must be printable for distribution to road crews.

- Ability to view user-modifiable treatment plans, to play “what if” scenarios for initial and subsequent treatments, showing probable results of each choice.

- Provide ability to perform “what if” scenarios for various topics including chemical application rate, type of chemical, and time of application. Shows the effect on subsequent road predictions and application suggestions.

- Provide graphs of weather and road data/predictions (`Prediction Background’) to augment and support the basis for the automated decisions.

- Include a final maintenance decision OK button to verify/accept treatment plan and log results.

- Provide ability to record chemical (e.g., salt and sand) inventory levels and indicated inventory levels.

- Include information on maintenance budget with funds remaining based on maintenance decision choices (i.e., treatment stocks used, salaries and overtime, truck operation and repairs, etc.).

- Provide an archive of previous weather/road predictions and recommended road treatments.

- Provide ability to graphically view historical data of predicted weather/road conditions vs. actual for post analysis.

- Provide full pull-down menus, selector buttons, text-entry boxes, color-coordinated icons/symbols, and direct access to all screens available at all levels – no “backing up” to maneuver through screens.

- Users indicate that the GUI must be fast, intuitive, easy to drive, fun to use, informative, and interactive with user and background data.

- The GUI must integrate other important information including, local weather forecast (text and graphics), neighboring district treatments, fire/police reports/emergencies, etc.

- The system must have a flexible setup (configuration capability) for initial installation or for future configuration changes (e.g., new trucks, new chemicals, new employees, new trigger levels, new treatment constraints, etc.).

- The MDSS should have an ability to view information from maintenance vehicles.

- The MDSS should provide a capability to export information so it can be viewed onboard DOT vehicles.

- The system should provide an ability to observe neighboring districts road maintenance decisions via a read-only function.

- The system should provide the ability for a mouse-click phone call from MDSS computer to multiple personnel (simultaneously) via user-definable lookup lists of primary and alternative phone numbers.

3. Risk Factors

The concepts listed here are still being developed and validated. Applying these concepts to existing or new technology will be challenging and may require further research, development, and validation.

APPENDIX D

MDSS Technology Description

MDSS Road Weather Forecasting System

Originating Organization: National Center for Atmospheric Research

Point of Contact Information:

Name: Bill Myers
Address 3450 Mitchell Lane, Boulder, CO 80303
Telephone # (303) 497-8412
E-mail address myers@ucar.edu

IP Restrictions: The holding and licensing of rights to intellectual property created with federal assistance is stipulated by the Bayh-Dole Act, as amended. Procedures implementing legislative and executive patent and licensing policy regarding "Rights to Inventions Made by Nonprofit Organizations and Small Business Firms" are codified at 37 CFR 401. Subject to these laws and regulations, MDSS prototype components shall be licensed for use at no cost in the MDSS operational test. Separate licensing arrangements subject to these laws and regulations shall be made for other tests and deployments. No intellectual property rights or other proprietary rights in the baseline systems are affected nor shall be surrendered under these provisions.

UCAR shall grant to the other party a limited, non-exclusive, non-transferable, revocable, royalty free right to access and use UCAR Intellectual Property only for the purpose of performing the work under this project. Separate licensing arrangements will be required for use of UCAR Intellectual Property outside the MDSS operational test.

Mode of Operation: It is envisioned that the Road Weather Forecast System will operate at NCAR and export data to the participating vendor and DOTs, where appropriate, during the MDSS operational test.

1. Introduction

a. General overview description. The MDSS Road Weather Forecasting System is a dynamic, integrated forecast system that uses routine data sources and standard computing hardware to create automated weather forecasts. The system has been designed to be open and highly modular so that it can incorporate new forecast data sources and techniques, and to be adaptable so that it can adjust to a changing forecast environment with varying weather regimes and fluctuating skill of the forecast inputs.

b. Scope. The MDSS Road Weather Forecasting System will produce forecasts of weather variables relevant to road weather maintenance. Forecasts will be generated at locations along or near the roadways. These forecasts can be used directly to make inferences about the atmospheric conditions along the roadway, and will also be used as input to road condition algorithms specifying the predicted road surface conditions. The weather forecasts outputs will be passed on directly to the vendors and made available to the road conditions algorithms.

c. Definitions, acronyms, abbreviations:

GRIB	GRIdded Binary
LDM	Local Data Manager
METAR	Surface meteorological observation
MOS	Model Output Statistics
NCEP	National Center for Environmental Prediction
NWS	National Weather Service
NOAAPort	A NWS meteorological data system
NETCDF	NETwork Common Data Format
RDBMS	Relational Data Base Management System
RWIS	Road Weather Information System

2. Technology Overview

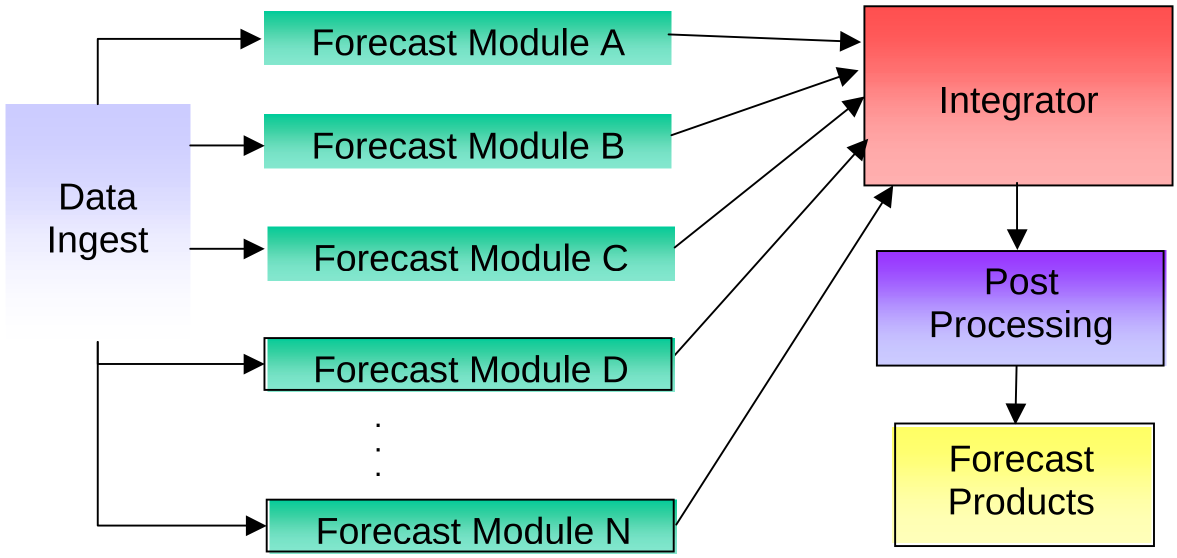
a. Functions. The Road Weather Forecast System ingests raw or processed weather data. It generates an ensemble of forecasts by applying a forecast generation technique to each data set. The forecast integrator does a fuzzy-logic intelligent combination of this ensemble of forecasts. The resultant forecasts then undergo quality control checks before they are exported.

b. Characteristics. The Road Weather Forecast System generates a new set of forecasts every three hours. Each new set of forecasts contains predictions for the next sixty (60) hours. The interval between forecast data points is three hours out to the 60-hour limit.

c. Constraints. The Road Weather Forecast System currently utilizes Internet access for delivery of its output forecasts. The input data can either be received via the Internet or through a satellite connection.

d. Dependencies. The Road Weather Forecast System produces better forecasts if all input data arrives in a timely fashion. However, it will still produce forecasts based on older data if the most recent data has not been received.

e. Road Weather Forecast System Data Flow Diagram. The Road Weather Forecast System ingests meteorological observations and forecast data (from numerical weather prediction models) and processes these data to generate several predictions for each point in space and forecast time. A fuzzy-logic integration process is used to generate the best weather forecast and associated probability information. The process is illustrated below.



3. Interfaces

a. System interfaces. The system runs on a single stand-alone computer system with a connection to the Internet for receiving input data and optionally distributing the end products.

b. Communication interfaces. The system must have a connection to the Internet to access NWS data. A NOAAPort receiver can serve as a primary or backup data source for several of the input data products.

c. Hardware Processing and Memory requirements. Hardware requirements vary depending on the number of sites forecast, but in general the system runs comfortably on a two-processor system with CPU speed of 450MHZ, 1GB RAM, and disk storage of 100GB. The system currently runs on Sun Sparc or Intel x86 based Solaris platforms.

d. Data input format. The system uses a variety of freely available data from the NWS. These data consist of observational data (METARs, synoptic reports) and NWS MOS products from NOAAPort received via the LDM, and NCEP model grids available on the NCEP ftp server. The input observations and MOS products are in ASCII text coded format, and the model data are in GRIB format. The system can also utilize meteorological information provided by RWIS.

e. Data output format. NetCDF is the file format used by the system. Output is also available in ASCII files or can be loaded into an RDBMS.

4. Description

a) Modules. Modules can be broken down into several groups based on functionality.

- *Data Assimilation Processes.* These processes decode, combine and convert incoming data to prepare it for subsequent use.

- *Forecast Module Processes.* These processes actually create the individual forecasts using a certain input forecast source or technique.

- *Empirics Processes.* There are several processes that are run to create empirical relationships between forecasts and observations, which are used in turn to improve future forecasts.

- *Forecast Output Processes.* Once the individual forecasts are generated, several processes are run to combine them into a final forecast, and perform any further miscellaneous steps such as creating derived variables, etc.

b) Error Handling. All processing errors are logged. In most cases, the failure of a single forecast module will not affect the system's ability to produce forecasts. In the event of the failure of a critical path component, no output will be possible at that forecast generation time.

c) I/O. In order to ingest the large NWS Numerical Weather Prediction model data sets, a relatively fast Internet (DSL) connection is necessary. The output data stream requires less bandwidth.

d) System Initialization. The Road Weather Forecast System integrator module tunes the weights applied to individual forecasts using observational data. Because of this, the system requires time to converge on an optimal set of weights. The initialization period for the system is approximately 100 days; therefore, it is important to have the system operating for approximately 100 days before the first forecast is issued. The system will issue forecasts from an initial set of weights, but its performance improves as its weights are adjusted.

APPENDIX E

MDSS Technology Description

Chemical Concentration Module

Originating Organization: CRREL

Point of Contact Information:

Marian P. Rollings, PhD, PE
CRREL
72 Lyme Road
Hanover, NH 03755
603-646-4822
mrollings@crrel.usace.army.mil

IP Restrictions: CRREL shall grant to the other party a limited, non-exclusive, non-transferable, revocable, royalty free right to access and use CRREL Intellectual Property only for the purpose of performing the work under this project. Separate licensing arrangements may be required for use of CRREL Intellectual Property outside the MDSS operational test.

Mode of Operation: During the operational test, the chemical concentration algorithms may be implemented by the vendor within the vendor's environment or on a separate processing system depending on the availability of key input parameters.

1. Introduction

a. General overview description. This module calculates the concentration of anti-icing or deicing chemical remaining on the roadway surface after an initial application and for any time period of interest afterwards.

b. Purpose. The purpose of this module is to provide guidance on roadway chemical concentration for purposes of identifying locations and times at which additional deicing and/or anti-icing chemical needs to be applied.

c. Scope. The module presently makes calculations for applications of "road salt" (sodium chloride), but can be modified to include other anti-icing and deicing chemicals.

2. Interfaces

a. System interfaces. The chemical concentration calculations are done in an Excel spreadsheet. The algorithm requires weather and operational data.

b. <u>Data input format</u>: ASCII files with latitude and longitude for point locations along the roadway of interest. Data inputs include:

precipitation type
precipitation rate
precipitation amount (on road)
air temperature (2 meter)
road temperature
road condition (initialization, wet, dry, etc.)
wind speed

c. <u>Data output format</u>. Chemical concentration values are generated at specified locations along the roadway.

3. Description

a. <u>Features and functions.</u> This utilizes a stepwise calculation that at each time interval calculates the anti-icing/deicing chemical concentration as a sum of salt existing in solution, residual salt present but not in solution, and salt from any new application during the time step. The concentration is adjusted for dilution by additional precipitation during the time step and for level of traffic. The strategy is to maintain the chemical concentration above the solubility phase diagram curve for the chemical (i.e., where all salt is in solution, while to the left of the curve ice and solution exist, to the right of the curve there is excess unneeded salt, and below the eutectic temperature all water freezes). The example in the attached spreadsheet is for sodium chloride.

b. <u>Output rates</u>. Output is at the same time intervals as weather data are available. The output interval for the MDSS prediction system will be 3 hours out to 48 hours.

4. Risk Factors

The chemical concentration algorithm as applied in this program represents a new technology. As such, the full functionality of this component is still under development. Applying this technology to new computing environments will be challenging and may require further research and development. Recipients of this technology should consider this risk.

APPENDIX F

MDSS Technology Description

Snow Drift Prediction Algorithm (SnowTran-3D)

Originating Organization: CRREL

Point of Contact Information:

Robert B. Haehnel
CRREL, 72 Lyme Road, Hanover, NH 03755
603-646-4325
rhaehnel@crrel.usace.army.mil

IP Restrictions: The Snow-Transport Modeling System - 3D (SnowTran-3D) that is being used within the MDSS project is proprietary and a license for use of this algorithm may be required.

Mode of Operation: During the operational test, the Snow-Transport Modeling System may be implemented by the vendor within the vendor's environment or on a separate processing system depending on the availability of key input parameters.

1. Introduction

a. General overview description. The snow drift algorithm is a model for predicting the redistribution of snow due to drifting on a 3-D terrain. The model handles transport of snow by saltation and suspension, and loss of snow due to sublimation.

b. Purpose. In the context of the MDSS, the snow drift model would allow a transportation specialist to view snow drift conditions resulting from the predicted weather event. In addition, the user could run the algorithm manually over a specified domain using manually entered weather inputs to evaluate the differences. This would allow the user to perform "what if" scenarios.

c. Scope. This section provides an overview of the Snow-Transport Modeling System.

d. References:

Liston, G.E, and Sturm, M. (1998) "A snow transport model for complex terrain," *Journal of Glaciology*, v. 44 (148) pp. 489-516.

2. Technology Overview

The algorithm performs the following steps:

- At each time step introduce meteorological data
- Update topography due to precipitation/drifting
- Compute wind field and surface shear
- Transport snow by saltation and suspension
- Compute sublimation
- Compute new snow depth
- Write out snow depth layer

3. Interfaces

a. System interfaces. Fortran 77 code, uses Unix scripts to preprocess input data for the model. Requires digital elevation model (DEM) and vegetation layers supplies as Gridded ASCII output files from a GIS system (e.g., ArcView).

b. User interfaces. GIS system (e.g., ArcView) for preprocessing vegetation and DEM layers and viewing snow depth output overlays (post processing). The model is run from command line (or cron script). Input parameters entered in text file.

c. Software interfaces. ArcView and Awk are used as the GIS system in the MDSS prototype.

d. Hardware processing requirements. Runs on a PIII 900MHz PC.

e. Memory requirements. Memory requirements (RAM) depend on domain size and resolution, 512MB RAM minimum.

f. Data input format. Digital elevation model (DEM) and vegetation (Land use-land cover, LULC) gridded data layers are needed for the domain over which the model is to run. Additionally, hourly meteorological data is needed to drive the model.

The meteorological data required includes:

surface air temperature (2 meter)
relative humidity (average)
wind speed and direction
solid precipitation (snow-water equivalent)

g. Data output format. Snow Depth over the domain in an ASCII grid file for import to GIS system (e.g., ArcView.).

3. Risk Factors

The snow drift algorithm as applied in this program represents a relatively new technology. As such, the full functionality of this component is still under development. Applying this technology to new computing environments will be challenging and may require further research and development. Recipients of this technology should consider this risk.

Image deleted to save space

Sample Output Image: This image shows the variation in snow depth over a domain. The black double lines indicate the major routes through the domain. The snow depth is bracketed as red, yellow, green, and clear to indicate level of service. Yellow areas indicate a reduction in snow depth (from the precipitation depth) due to local scour.

APPENDIX G

MDSS Technology Description

Automated Video Weather

Originating Organization: MIT Lincoln Laboratory

Point of Contact Information:

Name	Robert Hallowell
Address	244 Wood Street Lexington, MA 02420
Telephone #	(781) 981-3645
E-mail address	bobh@ll.mit.edu

IP Restrictions: Technology developed by the MIT Lincoln Laboratory is covered under the Bayh-Dole act, as amended. Private corporations may enter into licensing agreements with the MIT Technology Licensing Office for use of patented or copyrighted material. Technology transferred to private corporations as a result of federal funding is royalty free for federal, state and local government applications. However, the sale of this technology to foreign governments and private corporations or commercial users may be subject to restrictions (e.g., licensing agreements).

1. Introduction

a. General overview description. Traffic cameras are typically used to survey highways or key intersections throughout a city or state. Many traffic management centers (TMC) utilize these cameras to detect traffic build-up and trouble spots or accidents. However, these images also contain a wealth of information about the weather and road surface environment. Manual analysis to extract weather information, however, is time consuming and labor intensive. The video weather algorithm is designed to automatically calculate weather variables from a digital video image and disseminate a text message with the information.

b. Purpose. The purpose of this document is to describe the general algorithm to be used for extracting weather variables from video imagery.

c. Scope. This document details the overall structure of the algorithm and two specific modules for camera image processing: visibility and camera status. Other camera-derived weather variables are still in the design stage and are therefore not include in this technical description.

d. Definitions, acronyms, abbreviations:

IP	Intellectual Property
MDSS	Maintenance Decision Support System

MIT/LL	MIT Lincoln Laboratory
TMC	Traffic Management Center

2. Technology Overview

a. Functions. The basic function of the video weather algorithm is to provide visibility measurements that are derived from camera imagery. In addition, the algorithm will automatically detect conditions when the camera is blocked (by weather on the lens or traffic obstructions) or malfunctioning.

b. Characteristics. The algorithm operates on a series of images from the same camera over time. A composite image is kept of all the previous images to be used as both an image registration constant and as a basis for valid (long-term) objects in the image. An edge extraction algorithm is used to find edges of buildings, roads, bridges, horizon, etc. in the image. Each new image is compared against corresponding composite edges. Edges found in both images are kept as `expected' edges to be used for determining visibility. All other edges are considered `unexpected'; indicating rain on the lens or an obstructed view of the scene. These edges are used to diagnose bad camera images.

c. Constraints. The quality and accuracy of the visibility measures given are constrained by the range and variability of objects in the image. For example, a camera sited directly above an intersection will not be able to distinguish a visibility greater than the height of the camera. The ideal image would have both near and far edges, with a distribution of edges in between. We expect that some edges or objects in the image will need to be measured in order to calibrate the algorithm to a given image. The algorithm is (initially) only designed to work during daylight hours.

d. Block diagram:

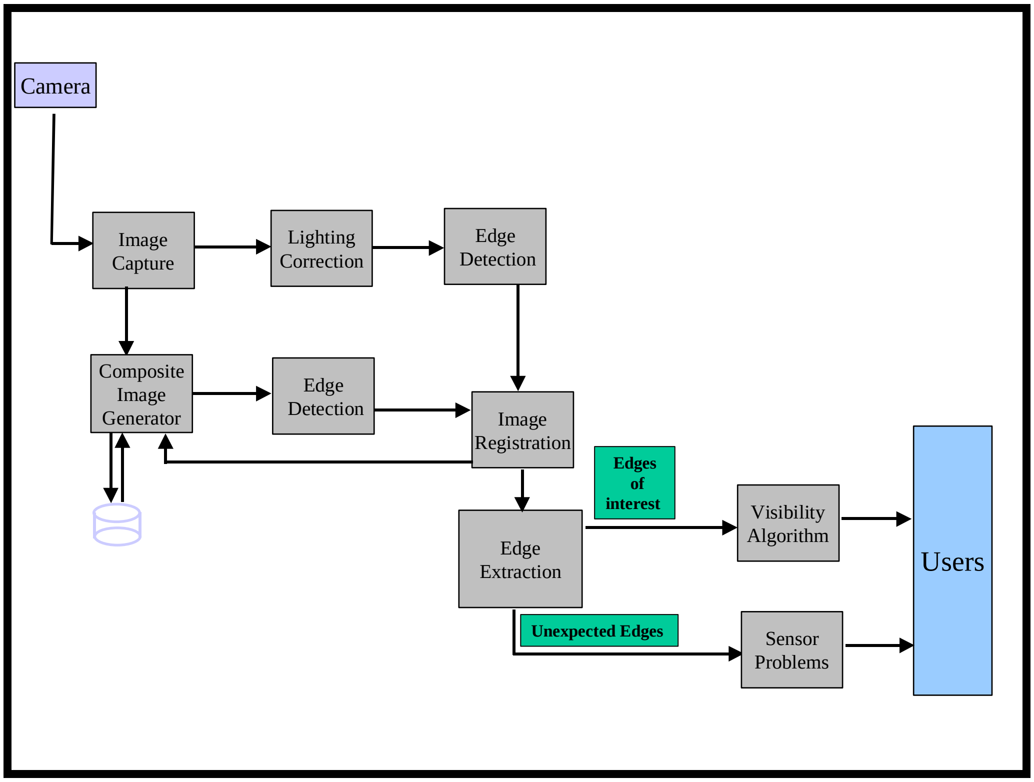


Figure 1 Overview of Video Weather Algorithm

3. Interfaces

a. System interfaces. The system is designed to operate on digital camera imagery and the prototype algorithm will utilize images in JPEG format. However, other forms of images could be easily re-formatted for inclusion in the system. The underlying algorithm requires access to site adaptable parameters (location, camera type, scoring functions (for converting various measures of the image to visibility), etc.). In addition, read/write access is needed to a composite image (see Technology Overview) for each camera being analyzed.

b. User interfaces. No specific user interface has been developed, however, we believe there are several ways to display this information to users. One might generate a table of camera locations with the ability to sort by visibility or status. In the MDSS, cameras will be viewed with video weather text overlaid on the image. In addition, this technology may be useful in prioritizing what cameras should be displayed to users. For example, cameras that are blocked could be excluded from a list of cameras available for display or cameras with critical levels of visibility may be given higher display priority. The status of the camera may also be useful in alerting camera maintenance crews of potential camera or site problems.

c. Hardware interfaces. An interface to camera imagery is needed, but the algorithm begins at the point where the imagery has been turned into a digital file. Therefore, no hardware interfaces are specified for this component.

d. Software interfaces. The video weather prototype utilizes two types of image processing libraries. The first is IDL (Interactive Data Visualization), which is a commercially available image processing software. The software may be obtained from:

Research Systems, Inc.
4990 Pearl East Circle
Boulder, CO 80301
http://www.rsinc.com

The second is a MIT/LL developed image processing library called csketch, which uses fuzzy logic to intelligently combine diverse types of interest images. Csketch would also be included in the transfer of technology to vendors (subject to the same IP restrictions as the overall algorithm).

These libraries may be interchangeable with other image processing libraries. Specifically, IDL is performing basic array and math functions that may also be available in other commercially available image processing software. The sketch library may be harder to replace because of the unique nature of the fuzzy-logic image processing being performed.

e. Communication interfaces. Other than direct input and output the algorithm stands alone.

f. Hardware processing requirements. It is unclear what the processing requirements will be for this algorithm; however, our minimal goal is to enable processing of 100 images within a 10-minute time frame on a single machine (1Ghz PC for example).

g. Memory requirements. It is unclear at this time what the memory requirements for this system will be.

h. Data input format. The system is designed to operate on digital camera imagery; the prototype algorithm will utilize images in JPEG format. However, other forms of images could be easily re-formatted for inclusion in the system.

i. Data output format. The final form of output may depend on the application. In its simplest form, camera visibility and status would be output as formatted text. The ability to output JPEG images highlighting visibility ranges is certainly technically possible, if a vendor desired such output.

4. Description

The immature nature of this algorithm does not allow for a detailed description of individual modules, features or functions. However, we have provided a general description of how each module (shown in Figure 1.) is designed to function.

a. Modules. The algorithm performs the following steps:

- *Image Capture:* Loads the next video image into memory.
- *Composite Image Generator*: Maintains an average image gray scale value over daylight hours (nighttime images are ignored).
- *Lighting Correction*: Each incoming image has a general correction applied to reduce the affects of lighting (glare/shadowing) on the image. The initial algorithm is quite simple. A clear day measure of the daily change in mean brightness of the image is used to calibrate the overall image.
- *Edge Extraction (Composite and Current Image):* A Sobel edge detection algorithm is run on both images and the edges are thresholded at a nominal value to leave only solid edges for analysis. All processing is performed in Cartesian arrays, on a pixel-by-pixel basis.
- *Image Registration:* The sobel edges are used to register the current image with the composite. Images that are shifted too much (10% or more) are thrown out. Note: cameras often shift due to winds or heavy precipitation.
- *Edge Extraction:* Current edges are compared with composite edges, pixels contained (above threshold) in both images are kept as \`expected' edges. All other edges are categorized as \`unexpected'. \`Expected' edges are then divided by composite edge values resulting in a normalized edge field. Values exceeding 1.0 represent edges that are stronger than its corresponding composite edge (indicating that the edge can be seen). Values less than 1.0 indicate edges that are becoming increasing hard to view.
- *Visibility Algorithm:* The \`expected' edges are sent to the visibility algorithm where the value of the individual \`expected' pixels are summed over the entire image. A normalized scoring function is used to estimate the overall visibility in the image. The normalized scoring function is based on the minimum and maximum viewing range in the

image, and previously derived normalization curves (either from the camera being used or a generalized model for any image).

- *Sensor Problems*: The ratio and nature of `unexpected' edges are used to determine if the camera sensor is having problems. Large numbers of unexpected edges may indicate rain or snow on the lens. Large numbers of unexpected edges in conjunction with limited expected edges may indicate a misaligned or out of focus cameras.

Note: The order of operations may potentially be modified as algorithm development continues. For example, we may decide to register images by comparing the full gray scale levels instead of just the edges. But, the modules listed here will all play basic roles in the algorithm.

b. <u>I/O</u>. Input to this algorithm is in JPEG format (although any 2-d imagery could be accommodated). Output is in the form of text indicating the status of the camera (sensor problems) and an estimate of the visibility along with a measure of the reliability of the measurement.

c. <u>Output rates.</u> It is expected that this algorithm would be able to execute as slow or as fast as the customer desired.

5. Risk Factors

The video weather algorithm, unlike some of the other algorithms in MDSS, is new technology being developed by MIT/LL. As such, the full functionality of this component is still under development. While general algorithm components have been defined and to some extent validated, applying this technology to new environments will be challenging and may require further research. Vendors should factor this risk into their decisions about the applicability of this algorithm for technology transfer.

APPENDIX H

MDSS Technology Description

Tailored Numerical Weather Forecasting System

Originating Organization: NOAA/Forecast Systems Lab

Point of Contact Information:

Name	Paul Schultz
Address	R/FS1, 325 Broadway, Boulder, CO 80303
Telephone #	303 497-6997
E-mail address	schultz@fsl.noaa.gov

IP Restrictions: The system is configurable so that there are no IP restrictions, but licensed products (e.g., forecast models, graphics engines, etc.) can be included.

Mode of Operation: During the MDSS operational test, the Tailored Numerical Weather Forecast System will be operated at FSL and send output to the NCAR Road Weather forecast System component. In addition, output (data and/or graphics) could be provided directly to the participating vendor and DOTs, where appropriate.

1. Introduction

a. General overview description. The Tailored Numerical Weather Forecast System ingests weather data (surface observations, radars, satellites, etc.) and outputs weather forecasts in various formats according to user requirements.

b. Purpose. Numerical weather forecasting via computer modeling has become cost-effective in recent years thanks to continuing growth in computing performance, but parallel growth in affordable telecommunications bandwidth has not occurred. Consequently, large centralized weather service providers, including the National Weather Service, are able to make highly detailed numerical forecasts but generally cannot deliver them in a timely manner in full resolution to their clients. Today, the most practical strategy for optimum numerical forecast services is to run the models locally; furthermore, a modeling system tailored to a local area is cost-effective in part because computing resources are not wasted on areas outside the local domain.

c. Operational concept. The Tailored Numerical Weather Forecast System is intended as a turn-key application that allows the user to run one or more forecast models configured according to needs, on whatever daily schedule which meets requirements. Although the original motivation for this development was to provide specific MDSS forecast elements to the NCAR MDSS Road Weather Forecast System, this Component can stand alone, providing forecast model output graphics with familiar look and feel, under the complete control of the user. The system can be tightly integrated into existing local operations, or the system can be operated remotely and send small- or large-volume outputs to various clients, depending on bandwidth and specific client needs. For the immediate future, this Component will be tested by running on FSL computers and electronically distributing forecast information.

d. Scope. This MDSS Component includes

a) computer system recommendations (including hardware and system software),
b) weather data ingest software,
c) several numerical models,
d) a graphical user interface to assist in configuring the models and managing data, and
e) postprocessing software, especially to produce the specific inputs required by the NCAR Road Weather Forecast System, but also including stand-alone graphics.

2. Technology Overview

a. Functions. The Tailored Numerical Weather Forecast System is designed to allow the user to establish an ensemble of model runs using various but similar models. Ensemble modeling has the advantage of producing forecast information that realistically represents the natural range of possible future states of the atmosphere that can evolve from the initial state. This in turn leads to estimates of uncertainty, which can be useful in decision-making applications. The system can also be configured to run models at the greatest possible spatial resolution. Maximum-resolution modeling has the advantage of being able to predict important small-scale weather events that are not captured on the coarser grids used in ensemble modeling. Of course, the user has options that allow for combinations of ensemble and maximum-resolution modeling techniques.

b. Characteristics. The system takes advantage of the relatively low expense of linux-based multiprocessor computers and weather forecast models that have been coded for parallel processing. This includes the workstation version of NWS's Eta model, NCAR/PSU's MM5 model, CSU/RAMS, ARPS, and the new WRF model now under development. This combination of hardware and software allows for great flexibility in configuring the system for specific tasks and taking maximum advantage of available resources.

c. Dependencies. The Tailored Numerical Weather Forecasting System can take advantage of virtually all meteorological data types, including radars, satellites, public and private mesonets, GPS water vapor, profilers, passive radiometers, and many more. At an absolute minimum, it requires access to gridded output from a forecast model that covers a superset of the local modeling domain, and produces forecasts that go farther out in time than the local forecasts. Positive incremental benefits from the inclusion of each of the additional datasets can be easily demonstrated.

3. Risk Factors

The Numerical Weather Forecast System as applied to road weather is new technology being developed by NOAA/FSL. As such, the full functionality of this component is still under development. While general system components have been defined and to some extent validated, applying this technology to new computing environments will be challenging and may require further research and development. Recipients of this technology should consider this risk.

APPENDIX I

MDSS Technology Description

Precipitation-Type Algorithms

Originating Organization: NOAA/National Severe Storms Laboratory

Point of Contact Information:

Name: John Cortinas
Address: 1313 Halley Circle
Telephone #: 405-366-0482
E-mail address: cortinas@nssl.noaa.gov

IP Restrictions: To be determined

Mode of Operation: During the MDSS operational test, the NOAA/NSSL Precipitation Type algorithms will be run within the NCAR Road Weather Forecast System component of the MDSS. Precipitation type output from these algorithms could also be provided directly to the participating vendor and DOTs, where appropriate.

1. Introduction

a. General overview description. The MDSS system includes three algorithms that diagnose the type of precipitation (e.g. rain, snow, freezing rain, and sleet) that is expected given the forecast state of the atmosphere provided by a numerical model. Each of these algorithms determines the most likely type of precipitation at a particular location based on an assessment of a vertical profile of dry-bulb and dewpoint temperatures at that location. Since these algorithms use different formulations for assessing the precipitation type, they have been integrated into the NCAR Road Weather Forecast System to provide the MDSS with an approximation of the precipitation-type forecast uncertainty.

b. Purpose. The purpose of these algorithms is to provide the user with a precipitation-type diagnosis based upon numerical model output.

c. References:

Baldwin, M., R. Treadon, and S. Contorno, 1994: Precipitation type prediction using a decision tree approach with NMCs mesoscale eta model. Preprints, *10th Conf. On Numerical Weather Prediction*, Portland, OR, Amer. Meteor. Soc., 30—31.

Bourgoin, P., 2000: A method to determine precipitation types. *Wea. Forecasting*, **15,** 583–592.

Cortinas, J.V., Jr., and M. E. Baldwin, 1999: A preliminary evaluation of six precipitation-type algorithms for use in operational forecasting. Proceedings, *6th Workshop on Operational Meteorology*, Halifax, Nova Scotia, Environment Canada, 207-211. <http://www.nssl.noaa.gov/~cortinas/preprints/canada6.html>

Ramer, J., 1993: An empirical technique for diagnosing precipitation type from model output. Preprints, *5th International Conf. On Aviation Weather Systems*, Vienna, VA, Amer. Meteor. Soc., 227—230.

2. Interfaces

a. User interfaces. Since these algorithms are internal to the MDSS, the current configuration requires no user interface.

b. Software interfaces. The algorithms are written as subroutines that require one-dimensional thermodynamic data at a particular location as input. The data that are needed at each level are pressure, dry-bulb temperature, and dewpoint temperature. There is no minimum requirement for the number of data levels, although fewer than ten would probably reduce the accuracy significantly.

c. Hardware processing requirements. The source code is written in Fortran and C, so any computer with either compiler is sufficient.

d. Data output. Each subroutine returns one value, the diagnosed precipitation type.

3. Algorithm Description

a. NCEP (also see Baldwin et al. (1994)). The National Center for Environmental Prediction (NCEP) algorithm currently is being used by the National Weather Service to generate precipitation type data for their forecasters. Using forecast sounding data, this algorithm quantifies the thermodynamic stratification and compares it to a set of empirically determined set of similar variables to diagnosis the precipitation type.

b. Bourgoin (also see Bourgoin (2000)). The algorithm written by Pierre Bourgoin is currently being used by the Meteorological Service of Canada to generate precipitation-type data for their forecasters. The procedure for computing precipitation type is similar to that used in the NCEP algorithm, except that different empirically determined values are used.

c. Ramer (also see Ramer (1993)). The Ramer algorithm diagnosis the state of a single hydrometeor as it falls from a generating level to the ground. Using the forecast sounding data, the algorithm computes how much melting and refreezing will occur as the hydrometeor descends through each atmospheric layer using fundamental thermodynamic principles.

4. Risk Factors

The precipitation-type algorithms, unlike some of the other components in MDSS, are algorithms that are currently being evaluated for accuracy. As such, the full functionality of this component is still under development and is uncertain. While these algorithms have been defined and to some extent validated, applying this technology to new environments may require further research. Vendors should factor this risk into their decisions about the applicability of this algorithm for technology transfer.